NASA STMD Landscape of SmallSat Capability Gaps

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NASA's Space Technology Mission Directorate

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SPACE TECHNOLOGY PORTFOLIO

EARLY STAGE INNOVATION AND PARTNERSHIPS

- Early Stage Innovation
  - Space Tech Research Grants
  - Center Innovation Fund
  - Early Career Initiative
  - Prizes, Challenges & Crowdsourcing
  - NASA Innovation Advanced Concepts
- Technology Transfer

SBIR/STTR PROGRAMS

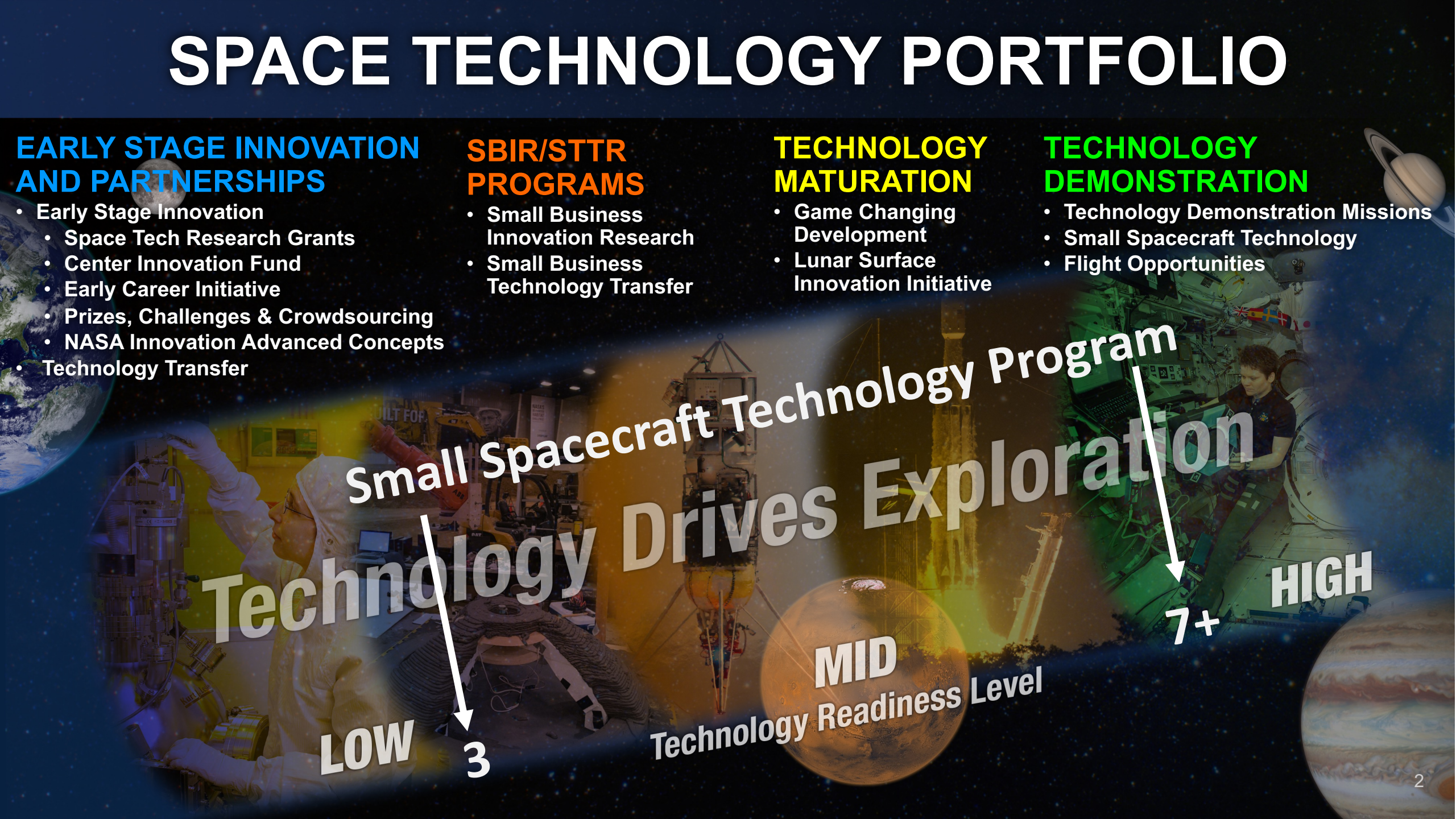
- Small Business Innovation Research
- Small Business Technology Transfer

TECHNOLOGY MATURATION

- Game Changing Development
- Lunar Surface Innovation Initiative

TECHNOLOGY DEMONSTRATION

- Technology Demonstration Missions
- Small Spacecraft Technology
- Flight Opportunities



EXPLORE SPACE TECH

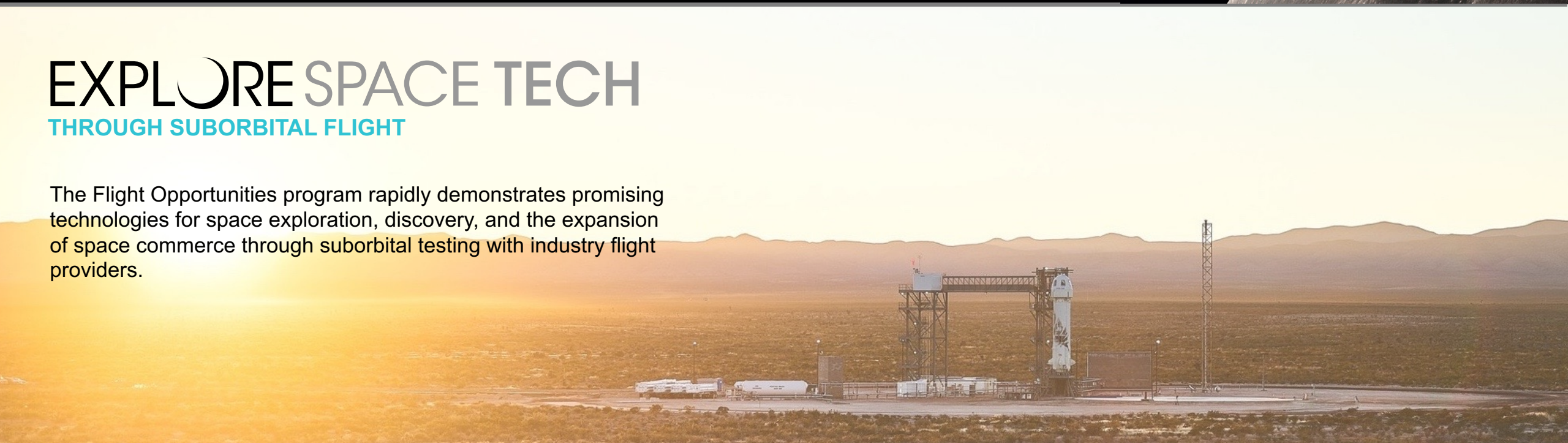
WITH SMALL SPACECRAFT

The Small Spacecraft Technology program expands the ability to execute unique missions through rapid development and demonstration of capabilities for small spacecraft applicable to exploration, science and the commercial space sector.

EXPLORE SPACE TECH

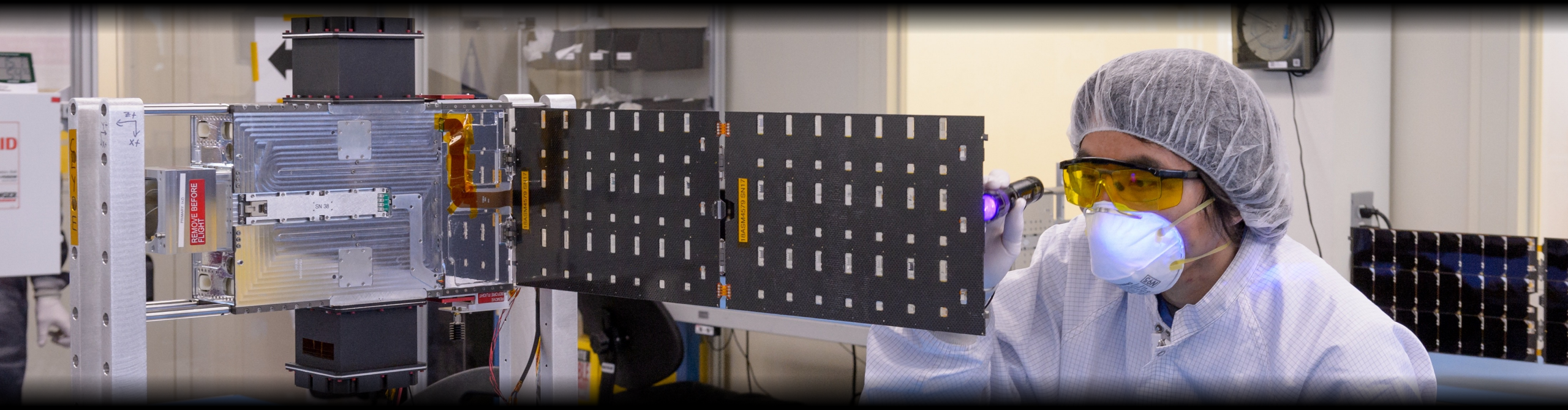
THROUGH SUBORBITAL FLIGHT

The Flight Opportunities program rapidly demonstrates promising technologies for space exploration, discovery, and the expansion of space commerce through suborbital testing with industry flight providers.



SMALL SPACECRAFT TECHNOLOGY & FLIGHT OPPORTUNITIES PORTFOLIO

The Flight Opportunities and Small Spacecraft Technology portfolio supports disruptive technology development and unique missions to **change the pace of space** exploration, discovery and space commerce.



Why?	• To **ensure American industry leadership** in space and **increase the rate of scientific discoveries** within our lifetimes.
How?	• Leverage commercial capabilities and best practices • Embrace risk-informed decision making and risk tolerance • Minimize NASA processes but leverage Agency expertise • Apply constraint-driven mission philosophy (cost / schedule) • Rapidly move from benchtop to flight test to de-risk technology • Maintain programmatic agility to ensure responsiveness to disruptive innovation and the changing geopolitical landscape

SPACE TECHNOLOGY MISSION DIRECTORATE'S STRATEGIC FRAMEWORK

Go

Rapid, Safe, & Efficient Space Transportation

- Nuclear Systems
- Cryogenic Fluid Management
- Advanced Propulsion

Land

Expanded Access to Diverse Surface Destinations

- Entry, Descent, Landing, & Precision Landing

Live

Sustainable Living and Working Farther from Earth

- Advanced Power
- In-Situ Resource Utilization
- Advanced Thermal
- Advanced Materials, Structures, & Construction
- Advanced Habitation Systems

Explore

Transformative Missions and Discoveries

- Advanced Avionics Systems
- Advanced Communications & Navigation
- Advanced Robotics
- Autonomous Systems
- Satellite Servicing & Assembly
- Advanced Manufacturing
- **Small Spacecraft**
- Rendezvous, Proximity Operations & Capture
- Sensor & Instrumentation

Lead

Ensuring American global leadership in Space Technology

- Advance US space technology innovation and competitiveness in a global context
- Encourage technology driven economic growth with an emphasis on the expanding space economy
- Inspire and develop a diverse and powerful US aerospace technology community

Learn more about NASA's critical technology needs at techport.nasa.gov/framework

EXPLORE SPACE TECH

CHANGING THE PACE OF SPACE

Leveraging small spacecraft and responsive launch to rapidly expand space capabilities at dramatically lower costs

Rapid Leap from Lab to Orbit

Commercial suborbital and orbital test capabilities de risking technology for future missions. Technology moves from lab to orbit in <9 months.

Responsive deep space access

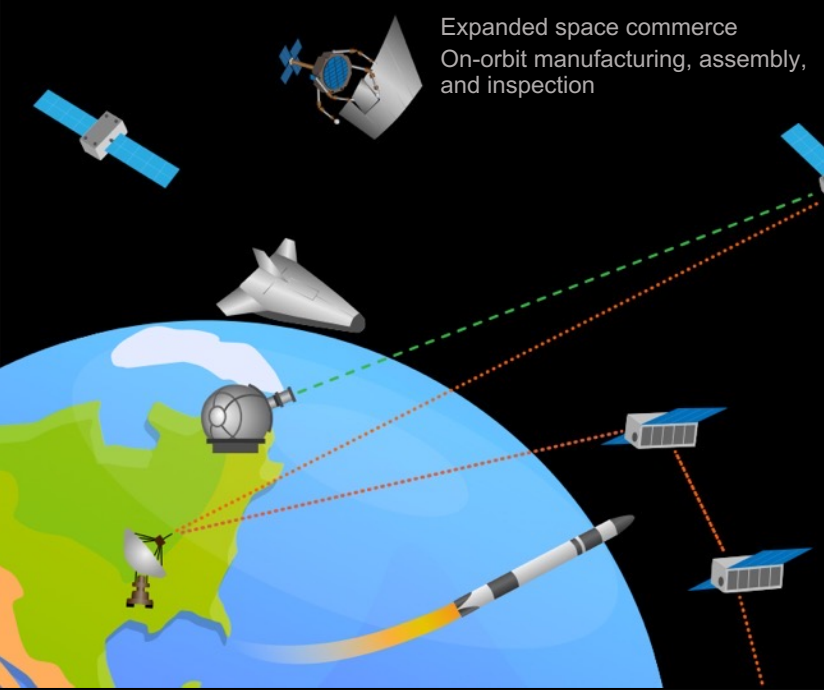
Sustained deep space presence

Commercial lunar activity

In-situ resource extraction and utilization

Expanded space commerce

On-orbit manufacturing, assembly, and inspection

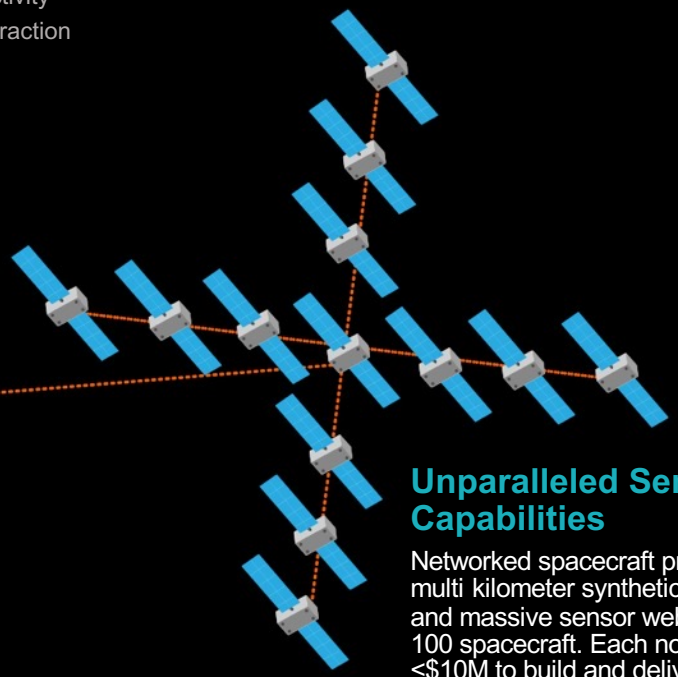


Unprecedented Deep Space Infrastructure

Modular communications, navigation, and mission support that provides full coverage of Moon and Mars. Each node costs <$20M to build and deliver to space.

On-Demand Missions Beyond Earth

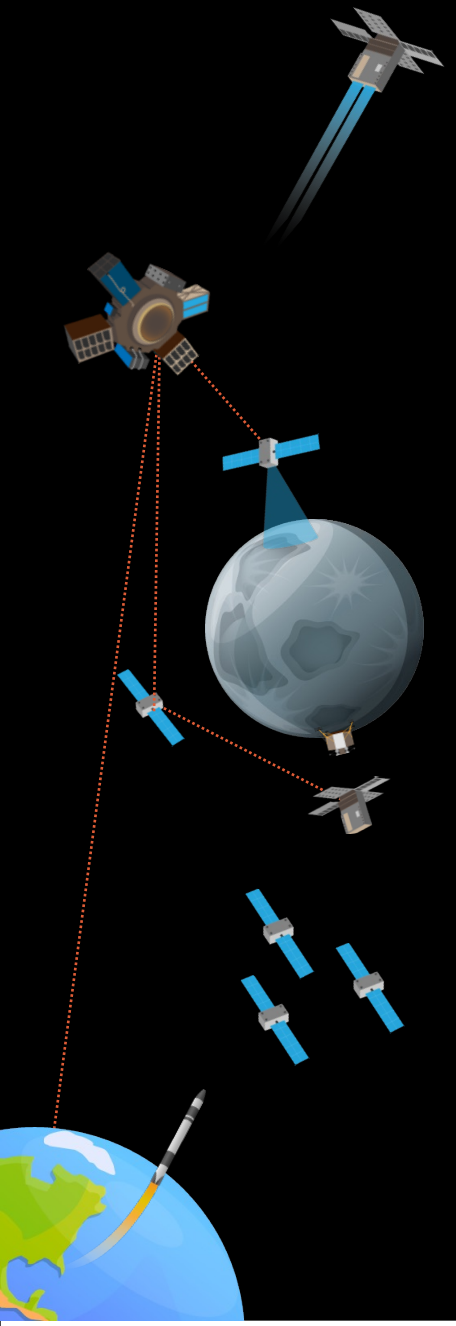
Targeted measurements of Moon, Mars, Venus, and the asteroid belt in response to events and opportunities. Capabilities are competitive with traditional systems but developed for <$30M in <3 years.



Unparalleled Sensing Capabilities

Networked spacecraft providing multi kilometer synthetic apertures and massive sensor webs of 30 to 100 spacecraft. Each node costs <$10M to build and deliver to space.

NOT ALL ACTIVITIES DEPICTED ARE CURRENTLY FUNDED OR APPROVED. DEPICTS "NOTIONAL FUTURE" TO GUIDE TECHNOLOGY VISION



CHANGING THE PACE OF SPACE: Envisioned Future For Small Spacecraft Technology

High dV Small Spacecraft Propulsion Systems

Low size, weight, power, and cost (SWaP-C) systems capable of imparting 2-5+ km/s change in velocity (dV) to microsatellites. Highly manufacturable and compatible with the deep space environment. ► Small missions to the Moon, Lagrange Points, NEOs and beyond as well as plane changes and more responsive missions in Earth orbit.

Deep Space Orbital Maneuvering Vehicles (OMVs)

OMVs capable of 10+ km/s dV and providing position, navigation, and timing (PNT) services and communications relay to deployed spacecraft or hosted payloads. Affordable and demonstrated in the deep space environment. ► Expansion of small risk-tolerant missions further beyond Earth and the ability to reach multiple destinations from a single launch.

In-Space Autonomy for Small Spacecraft and Distributed Systems

Significant (~75%) reduction in ground station aperture time for single small spacecraft missions. Increased in-space autonomy that allows 10's of small spacecraft to operate as a single unit beyond Earth. ► Large distributed missions (e.g., heliophysics) and missions in Earth-orbiting or beyond that can react without ground stations in the loop.

Small Spacecraft Communications and PNT Services

Small spacecraft that can be deployed to the Moon and other deep space destinations to provide global PNT and communications relay infrastructure. ► Addresses future strain on terrestrially-based capabilities (e.g., tracking) caused by concurrent cislunar missions and global surface missions where direct communications with Earth is not feasible.

Interoperable Networking for Small Missions

Increased interoperability between government and commercial space networks. Operational interoperability protocols that help pair the NASA DTN and LunaNet with the Hybrid Space Architecture. ► Ubiquitous communication between in-space assets, airborne systems, in-situ sensors, and ground assets as well as networking in cislunar space.

Small Spacecraft Proximity Operations and Abort Systems

De-risked low size, weight, power and cost (SWaP-C) proximity sensors and reliable proximity abort systems. ► Reduced risk in use of small satellites in close proximity to high value assets (e.g., for servicing / inspection) and for small missions to natural targets like NEOs.

Responsive Access to Suborbital and Orbital Space

Additional suborbital vehicle performance and payload accommodations for technology testing (e.g., payloads hosted on recoverable orbital launch vehicle stages and hosted orbital payloads). ► Rapid advancement of capabilities requires frequent risk-tolerant opportunities to test and evaluate in an operational environment.

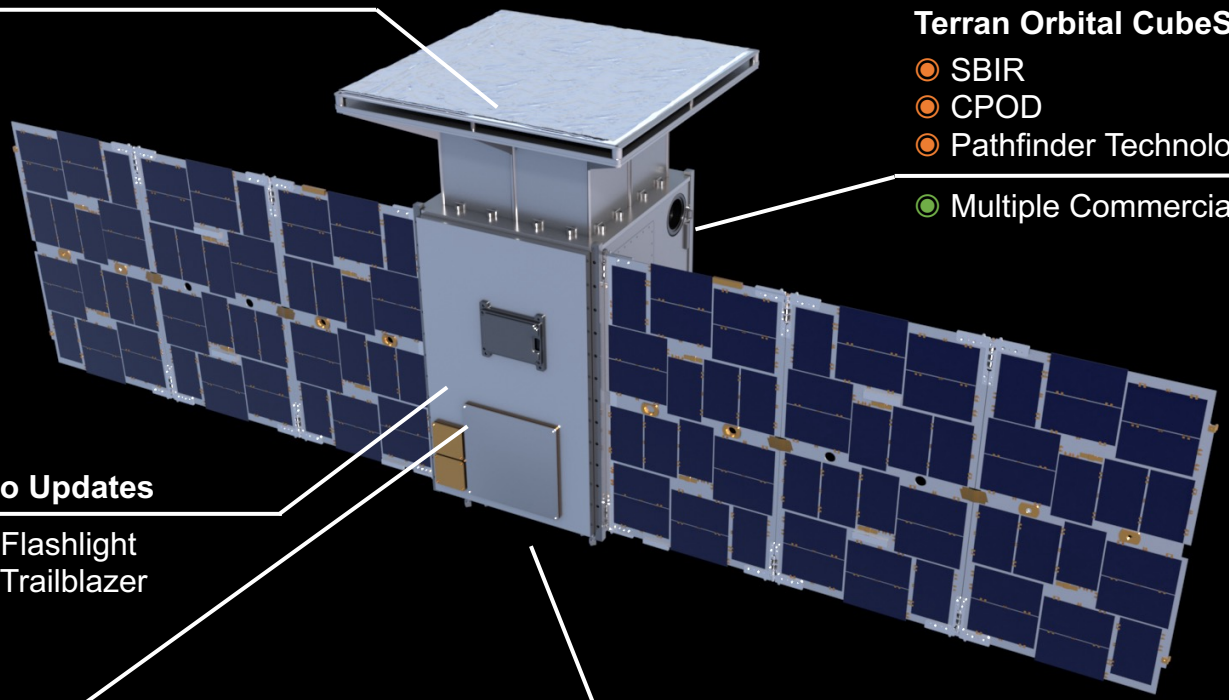
CAPSTONE

The Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE) is the first U.S. commercial mission to the Moon and the first spacecraft to demonstrate the unique lunar orbit intended for NASA's Gateway.

Cislunar Autonomous Positioning System (CAPS)
- SBIR
- ACO

Rocket Lab USA Interplanetary Photon
- NASA ESCAPADE

Tethers Unlimited SLX (Crosslink Radio)
- SBIR



Terran Orbital CubeSat Bus Systems
- SBIR
- CPOD
- Pathfinder Technology Demonstrators (PTD)
- Multiple Commercial and Government Missions

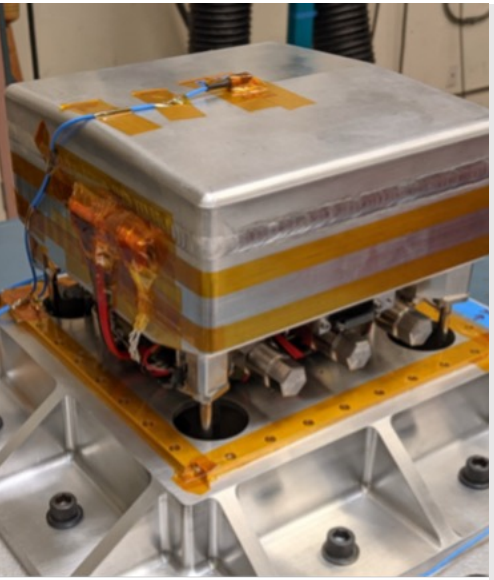
Iris Radio Updates
- Lunar Flashlight
- Lunar Trailblazer

Orion Space Solutions Chip Scale Atomic Clock
- SBIR

Stellar Exploration CubeSat Hydrazine Propulsion System
- SBIR
- Multiple Commercial and DoD Missions (Including an EchoStar Commercial Communications Satellite)

Key:
- Prior STMD Technology Investments
- Technology Transition / Infusion

SMALL SPACECRAFT TECHNOLOGY – CAPSTONE INFUSION HIGHLIGHTS TO DATE

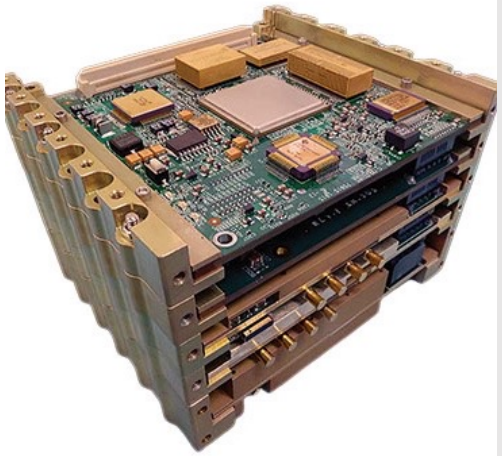


Propulsion System Commercial Infusion

First CubeSat hydrazine propulsion approved by range and launch safety.

Developed by Stellar Exploration Inc.

Used on a commercial mission in 2021 and performed largest known CubeSat orbit raising and inclination change maneuver.

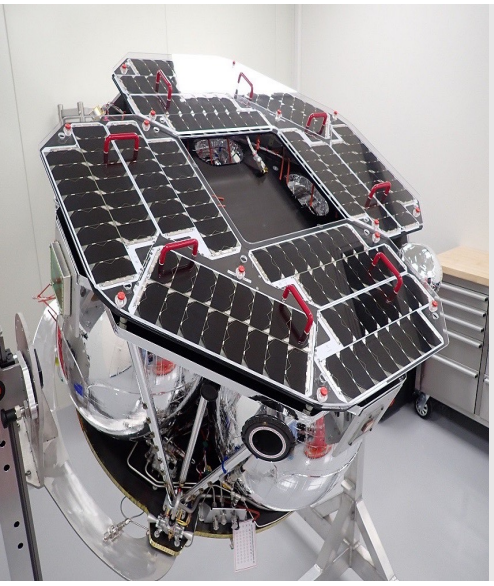


Iris Radio Upgrades and One Way Ranging Enhancement

JPL upgraded the Iris (deep space CubeSat) radio and added interface for a Chip Scale Atomic Clock (CSAC).

Missions (including Lunar Flashlight) have integrated radio communication and tracking performance enhancements.

One-way ranging capability enabled by the CSAC and new firmware.

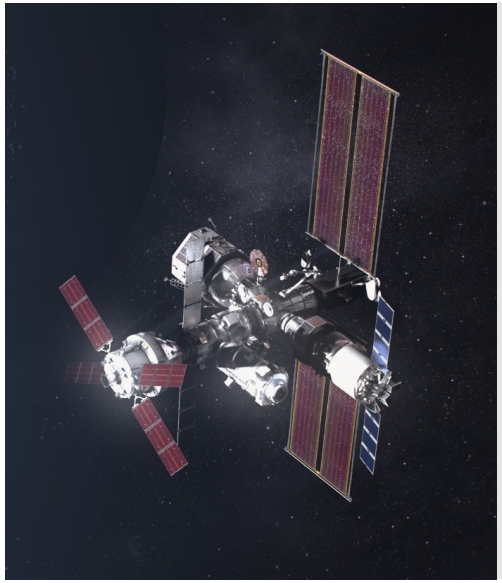


Interplanetary Transfer Stage Science Mission Infusion

Rocket Lab Interplanetary Photon stage designed to deliver CAPSTONE to TLI.

Two will be used for NASA's Escape and Plasma Acceleration and Dynamics Explorers (EscaPADE) mission to Mars.

Will be used for Rocket Lab's private mission to Venus.



Pathfinding for Artemis

In addition to the data that will be gathered in the NRHO, Advanced Space has been leveraging knowledge gained from CAPSTONE mission development in their support of NASA JSC FOD and the Gateway Program.

CAPSTONE performed in space testing for and provided data to the DSN and Artemis-1 CubeSats.

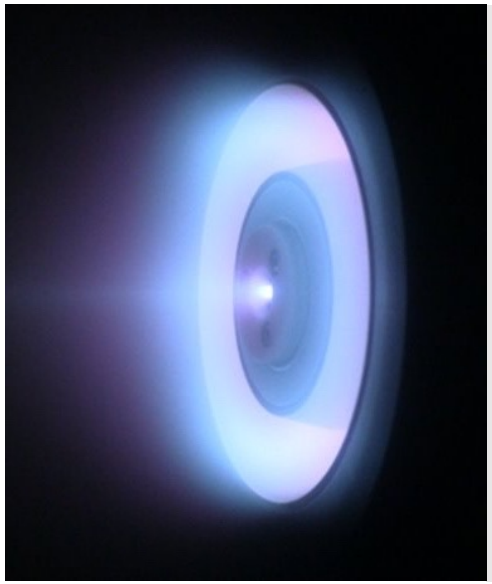
SMALL SPACECRAFT TECHNOLOGY – PROPULSION DEMONSTRATION MISSIONS

Advanced Composite Solar Sail System (ACS3)

Will test the in-space deployment of composite boom technology. When deployed, ACS3's four composite booms support an 80 square meter aluminized polymer solar sail, which will produce thrust from reflected sunlight.

Mission extension funded by SMD will demonstrate the first practical solar sailing in LEO

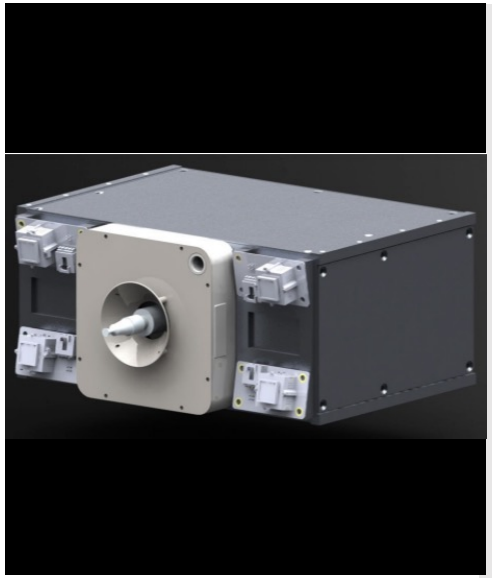
Orbital Flight Test



ExoTerra Courier SEP "Tipping Point" Commercial Partnership

Demonstration of a solar electric propulsion system for 12U CubeSat that includes a Micro Hall Thruster and high-power fold-out solar arrays. Targeting 1.27km/s dV.

Orbital Flight Test

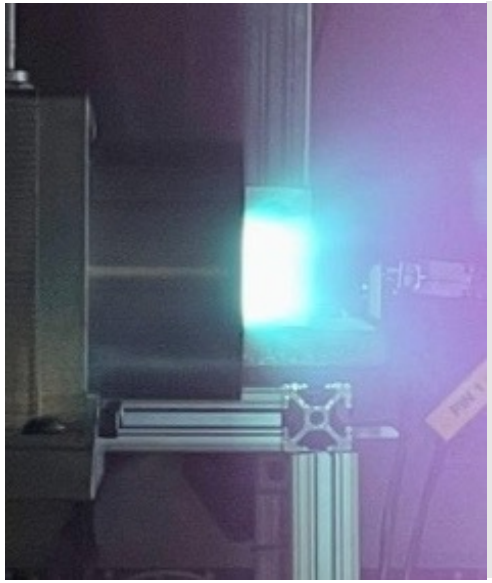


Green Propulsion Dual Mode (GPDM)

Demonstration of ASCENT-based dual-mode system that uniquely provides the capability of delivering in-space translation and attitude maneuverability for small satellites using a common propellant and feed system.

Utilizing both chemical and electrospray thrusters, enabling long life and maximizing efficiency and thrust.

Orbital Flight Test



Phase Four Maxwell "ACO" Commercial Partnership

Will estimate the expected lifetime of the thruster and inform future designs of RFT for small spacecraft missions requiring long duration propulsive maneuvers or large amounts of impulse.

Ground Test

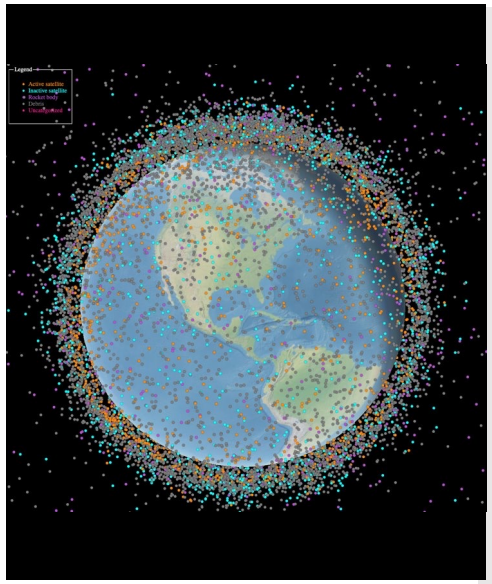
SMALL SPACECRAFT TECHNOLOGY – DISTRIBUTED SYSTEM DEMONSTRATION MISSIONS

Starling 1.0

Starling will use four CubeSats in low-Earth orbit to test technologies for multipoint science data collection and autonomous operations.

Test distributed mission capabilities for Earth observation and scientific discovery including ad hoc in-space networking, optical navigation for formation flight, and autonomous maneuvering / coordinated sensor driven operations.

Orbital Flight Test

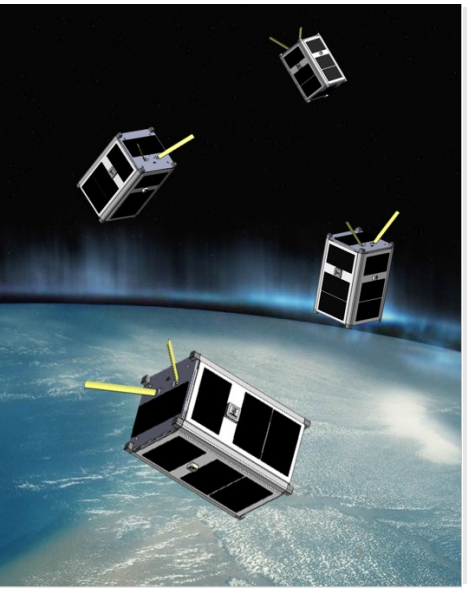


Starling 1.5

Extended mission (Starling 1.5) will develop technology and operational protocols for space traffic management approach in conjunction with Department of Commerce, NASA, CARA, and a leading industry partner.

The demonstration partner has the intention to used it operationally for coordination with other spacecraft owner-operators and then transition it to the Department of Commerce.

Orbital Flight Test



PY4

Demonstration of low SWaP-C spacecraft to spacecraft ranging, on-orbit topology determination, and coordinated measurements for future spacecraft swarm systems.

The demonstration uses four 1.5U CubeSats. This mission is a follow-on mission to V-R3x.

Orbital Flight Test

Opportunistic Software experiments for Spacecraft Autonomy Testbeds (OSE-Sat)

The project demonstrates a highly leverageable, efficient, and reusable solution to in-space computational resource-sharing computing architectures (DSA). In addition, the payload demonstrates the modularity of the DSA Comm app. 100 flight computer node system further demonstrating the extensibility of DSA that was flight tested on Starling 1.0.

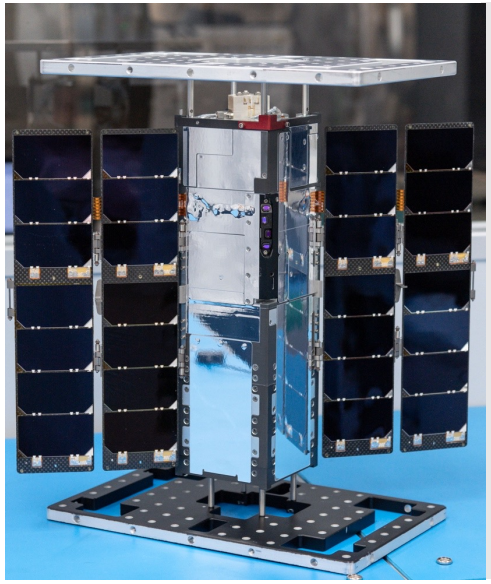
Ground Test

SMALL SPACECRAFT TECHNOLOGY – DISTRIBUTED SYSTEM DEMONSTRATION MISSIONS Cont.

DiskSat

DiskSat is a plate-shaped satellite 40 inches in diameter and an inch thick that could offer more power and surface area for instruments. Aerospace Corporation is leading design and development of a demonstration mission comprised of four DiskSats.

Orbital Flight Test



CubeSat Laser Infrared CrosslinK (CLICK)

CLICK will demonstrate full-duplex optical crosslink, timing exchange, and ranging between two small spacecraft. CLICK A is a risk reduction mission that will test elements of the optical communications system.

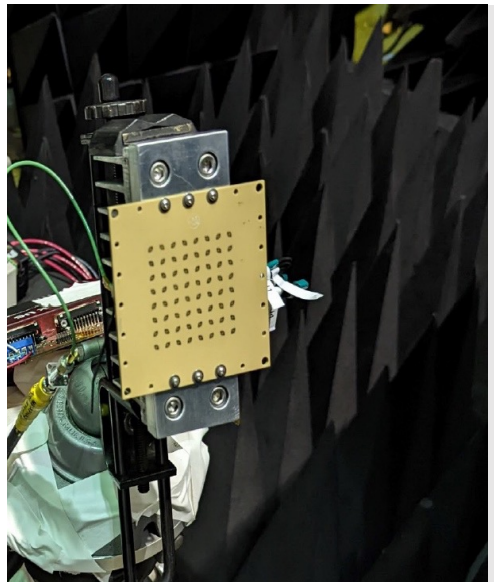
CLICK B/C will then demonstrate full-duplex simultaneous send / receive optical crosslink between two 3U CubeSats in low-Earth-orbit.

Orbital Flight Test

R5 Series (R5)

A demonstration of a rapidly deployable CubeSat bus built from commercial-off-the-shelf components. The bus is intended to primarily be used for in-space inspection activities and as a platform for demonstrating low-TRL payloads.

Orbital Flight Tests

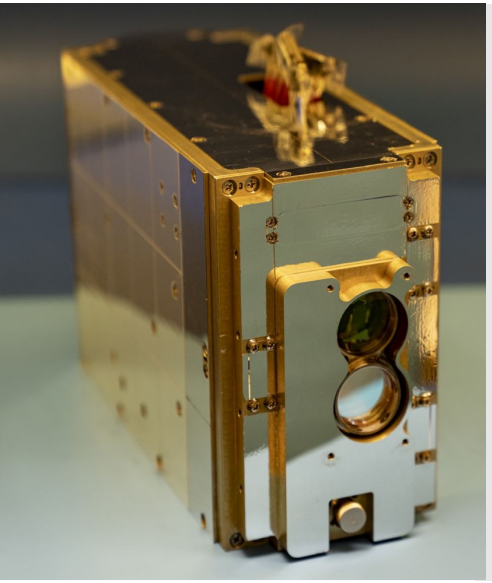


San Diego State University 5G Arrays for Lunar Relay Operations (FIGARO) University Partnership

Ka-band phased array antennas with commercial 5G Silicon Radio Frequency Integrated Circuit (RFIC) beamformer technology for space-based relay applications. Will be tested by Flight Opportunities on a commercial high-altitude balloon flight.

Suborbital Flight Test

SMALL SPACECRAFT TECHNOLOGY – INSTRUMENT SUPPORT TECH DEMONSTRATION MISSIONS

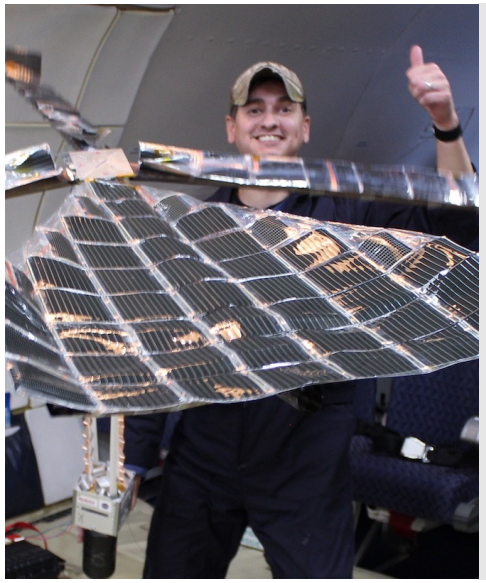


Pathfinder Technology Demonstrator-3 (PTD-3)

PTD is series of missions to test the operation of a variety of novel CubeSat technologies in low-Earth orbit.

The TeraByte InfraRed Delivery (TBIRD) communications system onboard PTD-3, the second to launch in the series, has achieved 200 Gbps data downlink rate.

Orbital Flight Tests

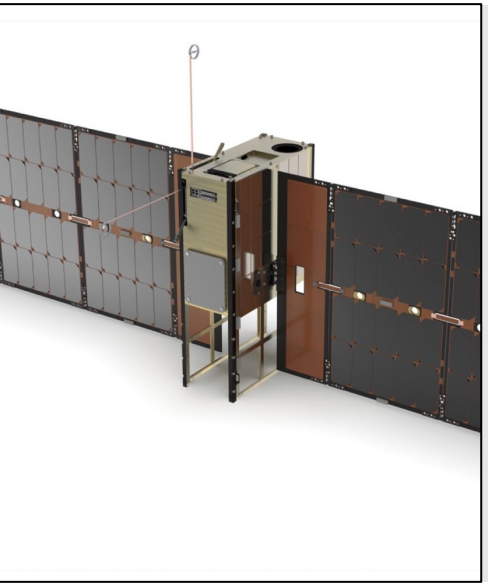


Pathfinder Technology Demonstrator - 4 (PTD-4)

PTD is series of missions to test the operation of a variety of novel CubeSat technologies in low-Earth orbit.

The mission will demonstrate the deployment, operation, and environmental survivability of the LISA-T power generation and communication array in a representative operational environment. Key performance parameter of specific power > 350W/kg.

Orbital Flight Test



Pathfinder Technology Demonstrator - R (PTD-R)

PTD is series of missions to test the operation of a variety of novel CubeSat technologies in low-Earth orbit.

The PTD-R mission will help further demonstrate ultraviolet (UV) and shortwave infrared (SWIR) monolithic telescopes from Lawrence Livermore National Laboratory.

Orbital Flight Test

Utah State University Active Thermal Architecture (ATA) for Cryogenic Optical Instruments University Partnership

Advanced thermal control system consisting of a deployable additively manufactured solar radiator, rotational fluid joint, and thermal isolation system for miniature cryogenically-cooled instruments hosted on CubeSats. Will be flown on the NASA ESTO ACMES mission.

Orbital Flight Test

SMALL SPACECRAFT TECHNOLOGY – ADDITIONAL ACTIVITIES

University SmallSat Technology Partnerships

University Small Spacecraft Technology Partnership Class 2023 (USTP)

Earth- and Global Navigation Satellite System-Independent Position Navigation and Timing for Small Spacecraft

Edge Computing and Machine-Learning Architectures, Software, Platforms, and Devices for Small Spacecraft

High Specific Power Systems and Thermal Control for Small Spacecraft

Tech Dev

SBIR·STTR America's Seed Fund™ POWERED BY NASA

STMD SBIR 2023

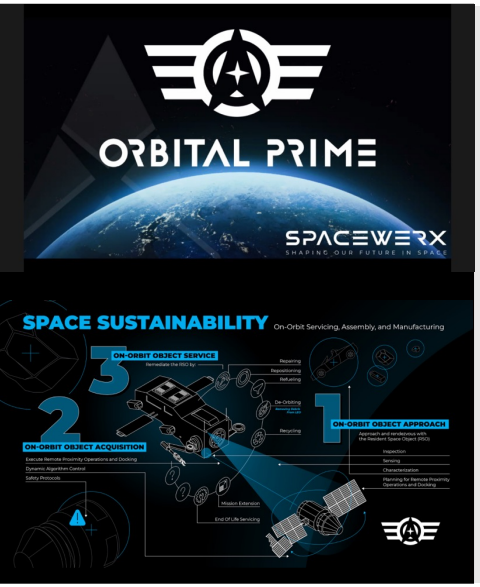
Actively managing solicitation, reviews, and awarded firms under:

2023 Phase I Small Spacecraft – 14 Awards

2022 Phase II – 4 Awards

2023 Phase II-S Sequential – 2 Awards

Tech Dev



Small Spacecraft Propulsion and Inspection Capability Study (SSPICy)

Leveraging AFWERX SBIR Phase 1 investments for in-space logistics companies, the SSPICy studies look to develop mission designs of previous awardees to perform in-space system level demonstration of small sat high deltaV propulsion, rendezvous and proximity operation, and inspection capabilities. 4 studies have been issued with commercial companies.

Mission Design Study

SmallSat State of the Art Report

Small Spacecraft Virtual Institute (S3VI) continues to aggregate and track state of the art in all small sat related fields on a yearly basis released in the annual SOA Report.

STMD Small Spacecraft capability gap development pull extensively from SOA.

Community Engagement

HELP IDENTIFY SMALL SPACECRAFT TECHNOLOGY GAPS

Contribute to:

Small Spacecraft Technology State of the Art Report

www.nasa.gov/smallsat-institute/sst-soa

Offer feedback:

Strategic Technology Framework

Go - Land - Live - Explore - Lead

techport.nasa.gov/framework

STAY ENGAGED:

NASA.GOV/SMALLSPACECRAFT

NASA.GOV/FLIGHTOPPORTUNITIES

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